EFFECTS OF FIRE AND REHABILITATION SEEDING ON SAGE GROUSE HABITAT IN THE PINYON-JUNIPER ZONE

An Extension of the Great Basin Pinyon-Juniper Demonstration Area

Final Report to the Joint Fire Science Program

Project #01B-3-3-01

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EXECUTIVE SUMMARY

Overview

Throughout much of the western United States, expansion of pinyon and juniper species into sagebrush ecosystems is altering the structure and composition of sagebrush communities and resulting in increased fire frequency, severity, and size. Increased tree densities in combination with altered fire regimes are having negative effects on both sagebrush communities and sagebrush obligates, including sage grouse, a species under consideration for listing as threatened or endangered. Maintaining and restoring habitat of sagebrush obligate species is becoming a management priority, and both local and regional fire management plans need to consider the effects of proposed actions, including prescribed fire, on the habitat of sagebrush obligate bird species. This study used the existing Great Basin Demonstration Project (#00-2-15) to examine the effects of prescribed fire on the habitats and bird species within the pinyon-juniper zone. It addressed the following information needs: (1) The effects of fire on soil erosion and vegetation composition and structure of sagebrush communities over the elevational and tree density gradient that typifies the pinyon-juniper zone in the Great Basin. (2) The effects of rehabilitation seeding with mixtures dominated by introduced vs. native species on vegetation composition and structure of sagebrush communities over the elevational and tree density gradient that typifies the pinyon-juniper zone in the Great Basin. (3) The effects of fire on the survival, seedling establishment, and nutritional value of plant species used by sage grouse within the sagebrush communities typically found in the pinyon-juniper zone of the Great Basin. (4) The presence, abundance, and location of sagebrush obligate bird species over the tree density and elevational gradient that typifies the pinyon-juniper zone within the study drainages, and changes that occur in patterns of use following fire. This effort utilized an integrated, collaborative project of the Joint Fire Sciences Program to address each of these information needs. The project duration was from May 15, 2002 to May 15, 2006. A third project was funded through the JFSP in 2005 on "Response of Birds, Butterflies and their Habitats to Management of Wildland Fuels and Fire Regimes" that will further extend this research.

Deliverables

The project deliverables as outlined in the initial proposal are provided below, and are used as a framework for organizing the report. Primary products are listed in text and a complete list of products is found at the end of the Report.

- A demonstration area that can serve as an example of using burn mosaics to improve sage grouse habitat.
- Guidelines for evaluating the effects of fire on sagebrush community and soil response to prescribed burns over the range of tree densities and elevational gradients that characterize pinyon-juniper woodlands.
- Guidelines for evaluating the effects of rehabilitation seeding on sagebrush community and soil response to prescribed burns over the range of tree densities and elevational gradients that characterize pinyon-juniper woodlands.
- Information on the effects of fire on the survival, establishment, and nutrient quality of plant species used by sage grouse.

- Information on the presence, abundance, and location of sagebrush obligate bird species within the study drainages, and on changes in use patterns following burning.

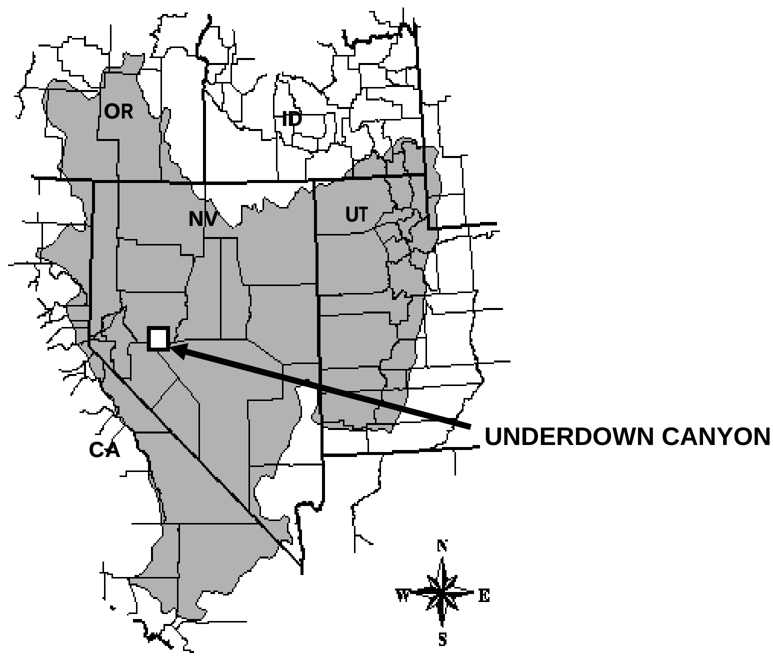
A long-term demonstration area has been developed to study the effects of spring-prescribed fire on pinyon-juniper woodlands and their associated sagebrush ecosystems. Information on the effects of spring prescribed fire on soil infiltration over the elevational and tree density gradient within the watershed was included in the Final Report for #00-2-15, and the summary publications are included herein (Rau 2005; Rau et al. 2005). Changes in vegetation composition over the same gradients were evaluated for the first three years after the fire (2002, 2003, and 2004) (Dhaemers et al. 2006; Dhaemers and Chambers *in preparation*) and will be monitored again in 2006. Because of low initial establishment of plant species used in the rehabilitation seeding, there were few detectable effects of the seeding and these data are not included. The plots will be reevaluated in 2006, and it is anticipated that this information will be included in the next report. Detailed analyses were conducted of the soil physical and chemical response of mid elevation sites within the Demonstration Area (Rau et al. 2005). Long-term data (5 years) have been collected on these sites on the responses of two soil nutrients critical for plant growth (nitrogen and phosphorus) (Rau et al. *in process*). The information on the soil responses on these sites have been related to changes in plant nutritional value after fire with a focus on species used by sage grouse (Rau et al. 2005; Rau et al. *in process*). In addition, information on the establishment of plant species used by sage grouse and other sagebrush obligate species on both burned and control sites has been obtained (Board et al. *in preparation*.) Data on the presence, abundance, and location of sagebrush obligate bird species were collected throughout the watershed and an adjacent control one year prior to the burn and every year since the burn. These data have been used to examine patterns and potential degree of nestedness; elevational influences on species richness; effects of spatial scale on species composition; patterns of spatial autocorrelation of assemblages of birds, floristics, physiognomy, and primary productivity; and remote sensing variables as predictors of species richness of birds (e.g., Fleishman et al. 2002, Seto et al. 2004, Fleishman and Mac Nally 2006).

Complimentary research that has been conducted on the Demonstration Area includes an assessment of the effects of fire and tree density on ant populations over the elevation gradient within the watershed (Mont Blanc 2005; Mont Blanc et al. *submitted*). In addition, research has been conducted on allometric methods for simulating plot biomass and fuel loads for single leaf pinyon and techniques for quantifying litter biomass (Tausch *in review*). This research is listed in the products section, but is not reviewed in this document.

The demonstration area has been used for illustrating the ongoing changes in central Great Basin pinyon-juniper woodlands and their associated sagebrush ecosystems to researchers, managers, NGOs, tribes and private individuals. It also has been used to show the effects of prescribed fire on these ecosystems. This has been accomplished through field tours from 2000 through 2005 and personal tours led by the PIs and their students. Additionally, study results have been presented at regional, national, and international meetings. The information obtained from the Demonstration Area is being incorporated into guidelines for the management of these ecosystems.

The Demonstration Area

The Demonstration Watershed was established as a collaborative effort between the USDA Forest Service, Rocky Mountain Research Station and Humboldt-Toiyabe National Forest, and the Nevada Bureau of Land Management. It is located in Underdown Canyon (39.1511°N 117.3583°W) in the Shoshone Mountain Range on the Humboldt-Toiyabe National Forest (Austin Ranger District) in Nye and Lander Counties, Nevada. Riley Canyon, a neighboring watershed, serves as a control. The geology of the watersheds consists of welded and non-welded silica ash flow tuff, and the soils developed on the alluvial fans used for the research burns are classified as Coarse loamy mixed frigid Typic Haploxerolls. Average annual precipitation ranges from 23 cm at the bottom to 50 cm at the top of the drainage and arrives mostly as winter snow and spring rains. Both watersheds have streams which are ephemeral during most years.



The original study was developed to examine both watershed-scale and stand/community-scale effects of the burn treatment. Studies of the effects of the burns on stream channels and water quality and also on butterfly taxa were designed to be examined at the watershed scale. Studies of fuel loads and of vegetation and soil responses were designed to be evaluated at the community scale. For the community-scale studies, three pairs of study sites (n=6) were located on north facing alluvial fans in June 2000 at elevations of 2073, 2103, 2195, and 2225; two sites were at 2347m. The fans range from two to six hectares in size. One of each pair of fans received the burn treatment, while the other served as a control. To evaluate the effects of burning over the elevational gradient, three macroplots ($0.1ha^2$) with intermediate tree densities were located on all burn and control sites. To examine the effects of burning on plots with different tree cover and fuel loads, three high tree cover and three low tree cover macroplots also were located at the mid-elevation sites (2195 and 2225m). Tree covers averaged 20% for low cover plots, 38% for intermediate cover plots, and 78% for high tree cover plots. The community-scale burns were conducted in spring 2002 (May 11-14) by interagency fire crews. Despite fairly moist conditions at the time of the burn, every attempt was made to obtain uniform burn conditions. The community-scale burns were designed to be a part of larger watershed-scale burns. However, due to a restrictive burn window and concerns over potential escape, only the smaller-scale burns were conducted in 2002. Because of high winds and an inability to obtain the necessary conditions for the burns, the watershed-scale burns were again postponed in 2003. During the third try in 2004, an additional 900 acres were treated resulting in a mosaic of burned and nonburned conditions within the watershed.

Soil Responses to the Prescribed Burn

The effects of the prescribed fire on the responses of nitrogen and phosphorus were examined at the mid elevation burn and control plots immediately before and after the spring burn, the fall prior to the burn, and for 4 falls after the smaller-scale burns. This information has been published in a Master's thesis (Rau 2005) and a manuscript is in process (Rau et al. *in process*). Specifically, the effects of prescribed fire, vegetation type, and time following fire on soil KCl extractable nitrogen and $NaHCO_3$ extractable phosphorus were evaluated. Nitrogen and phosphorus status of soils several years following a fire can dramatically influence the site's recovery potential. We found that KCL extractable NH_4^+ increased immediately following prescribed fire especially in sagebrush microsites. Extractable NO_3^- decreased immediately after the burn with the largest losses possibly occurring under pinyon pines. However, total extractable inorganic-N increased following the fire especially under sagebrush indicating that NH_4^+ increases out weigh NO_3^- decreases and dominate available N pools immediately following fire. Sodium bicarbonate extractable ortho-P increased immediately following fire.

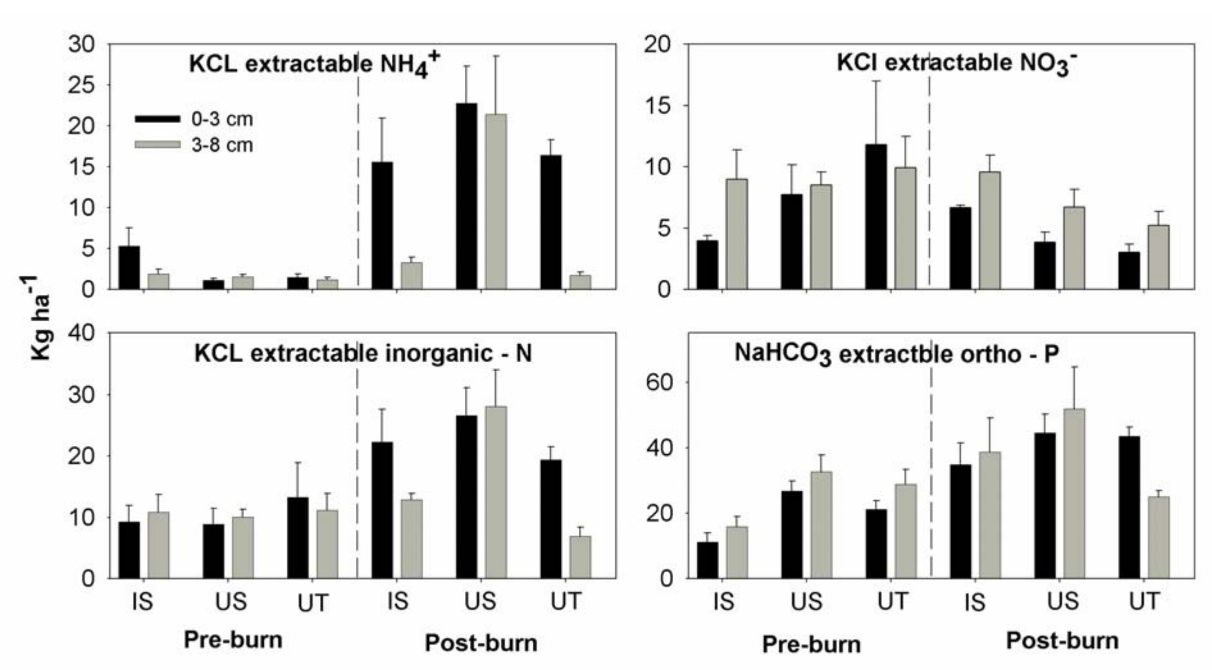


Figure 1. Means and standard errors for pre and post burn soil nutrients on the treatment site at two depths (0-3 and 0-8 cm) and three microsites (interspace, under shrub, and under tree).

In the four years following the fire microsite differences became less obvious but landscape scale trends continued. In the first 8 cm of the soil profile extractable NH_4^+ remained elevated through 2003 over the control with a similar trend through 2005. Extractable NO_3^- and total extractable inorganic-N remained elevated over the control through 2004 with the trend continuing through

2005 indicating that NO_3^- dominates longer term N availability near the soil surface. Fire increased extractable ortho-P on the burn site near the soil surface through 2003, and an obvious temporal increase occurred on both sites in 2003.

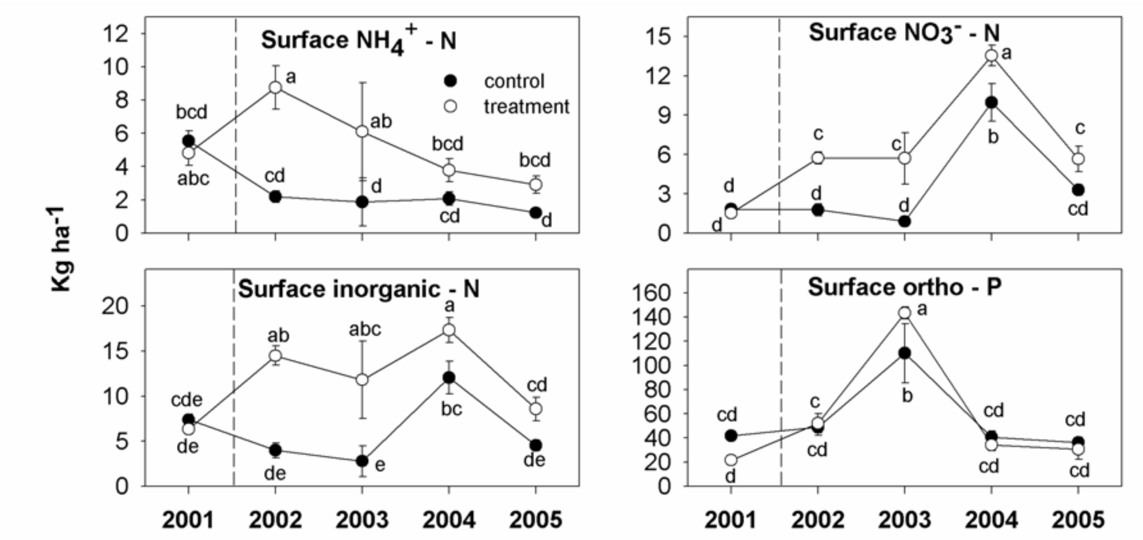


Figure 2. Means and standard errors for pre and post treatment near surface soil nutrients on the control and treatment sites. Means not represented by a common letter are significantly different.

Burn effects on NH_4^+ were not noticeable over longer time periods through 52 cm of the soil profile. However, NO_3^- and total extractable inorganic-N remained elevated over the control through 2002 and the trend continued into 2003 to 52 cm. There was also an obvious temporal peak in NO_3^- and total inorganic-N in 2004 for both sites to 52 cm. No fire effects were observed for extractable ortho-P to 52 cm, but the temporal peak appears on both sites in 2003.

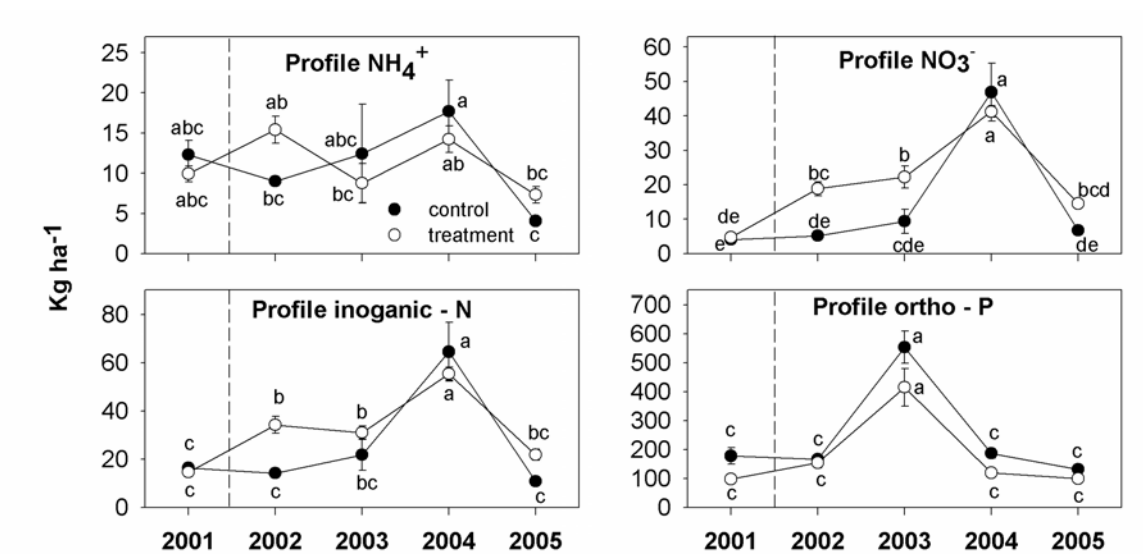


Figure 3. Means and standard errors for pre and post treatment soil nutrients through the profile on the control and treatment sites. Means not represented by a common letter are significantly different.

These results indicate that pinyon-juniper woodlands and their associated sagebrush semi-dessert communities are highly variable in regards to the spatial and temporal distribution of mineral nutrients. As woodlands expand into semi-arid shrub communities we may see a homogenization of soil nutrients across the landscape as tree crown cover becomes more continuous, and a shift in distribution of nutrients to the soil surface associated with litter fall. Increasing tree cover will also increase the proportion of nutrients stored in above ground biomass. These effects could prove to be deleterious if associated with high intensity wildfire, because losses from volatilization, convection, and erosion could increase. Soil available nutrients in woodlands change from one year to the next due to climatic variability; this complicates the analysis of fire effects, and emphasizes the need for representative controls. Prescribed burning in woodlands can cause immediate and persistent effects on soil available nutrients. Because fuel and soil moisture is high during spring prescribed burning, soil heating only occurs to shallow depths. The results are positive changes in soil available nutrients. Burn effects can be limited to surface soils and specific microsites, or they can occur at soil depths of 52 cm across the entire landscape. We have documented that these effects can persist up to four years following a prescribed burn. This may prove beneficial to vegetation recovering on the burn site. From a soil nutrient standpoint prescribed burning in our demonstration woodland can be a successful treatment for restoring sagebrush semi-desert ecosystems. However, for extrapolation to other sites it is important to consider the pre-existing understory vegetation conditions before burning, due to its influence on soil stability and site recovery post-burn.

Plant Community Response to the Prescribed Burn

The effects of elevation and tree cover on the vegetation recovery of the sites following the prescribed burns were examined in 2002 and 2004. In addition, the change in the cover of forb species used by sage grouse as a result of the burns was evaluated. These data are being summarized in a Master's thesis (Dhaemers 2006) and in a manuscript that is in preparation (Dhaemers et al. *in process*). Total herbaceous cover increased over the elevational gradient within the watershed regardless of treatment (Figure 4). Herbaceous cover increased on all burn sites between 2003 and 2004 while decreases were seen on the low elevation control plots. Total herbaceous aerial cover on burn sites exceeded that of their paired control plots in 2004 at all elevations.

Burning resulted in an increase in annual forb cover. However. similar increases occurred at all three elevations. A significant increase in annual grass was seen on burn plots, which is important because the only species in this functional group is *Bromus tectorum* L. However, this species still made up less than one percent of the overall cover on any site regardless of treatment. Perennial forb cover increased with elevation independent of treatment. Also, burned plots had greater cover than their paired control plots at all elevations. Similarly, the analysis for perennial graminoids showed significant effects of burning and elevation. Perennial graminoid aerial cover was similar at the low and intermediate elevations while the high elevation sites showed much higher cover of this functional group for both burn and control plots in both years.

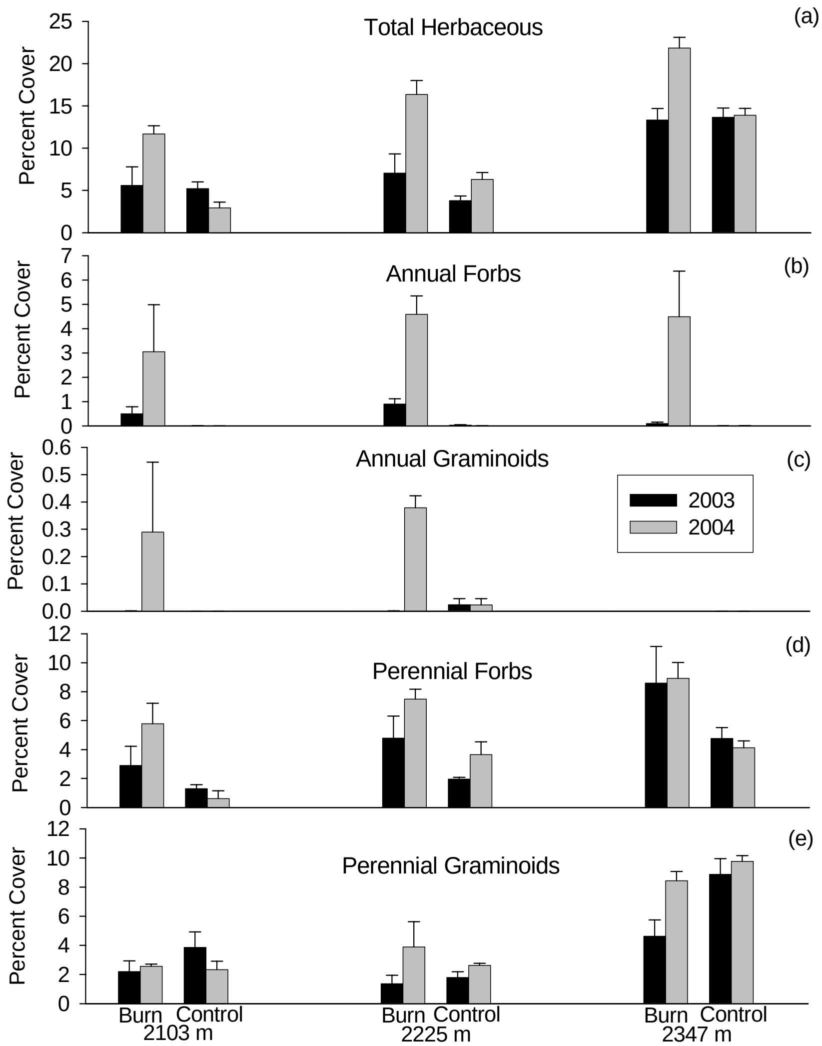


Figure 4. Aerial herbaceous cover for burn and control plots over three elevations in 2003 and 2004. Values are means ± standard error.

There was an overall effect of tree cover on total herbaceous cover and a burn effect (Figure 5). As tree cover increased, total mean herbaceous aerial cover decreased on both burn and control plots. However, cover was higher on burn plots than their paired control plots in 2004. Annual graminoid cover decreased as tree cover increased. Annual graminoids showed a significant increase on burn sites between 2003 and 2004, with the highest cover occurring on the low tree cover sites in 2004. Annual forb cover was significantly higher on burn sites than control sites, and burn sites showed a dramatic increase between 2003 and 2004 in annual forb cover. Perennial forbs showed similar patterns to annual graminoids, decreasing as tree cover increased. Perennial forbs recovered on burn sites to values equal to or greater than that of their paired control sites by 2004, showing a strong burn effect. Burning and tree cover showed significant effects individually and also showed a significant interaction for perennial forbs. Control plots showed a significant decrease in perennial forbs as tree cover increased. Perennial graminoids also decreased as tree cover increased. However, they seemed to decrease at a lower rate than other functional groups. There was a significant decrease in aerial cover for control plots as tree cover increased. Cover values for 2004 burn sites exceeded the cover on their paired control sites in all cases for perennial graminoids, but no significant effect of tree cover or significant differences between burn plots were seen.

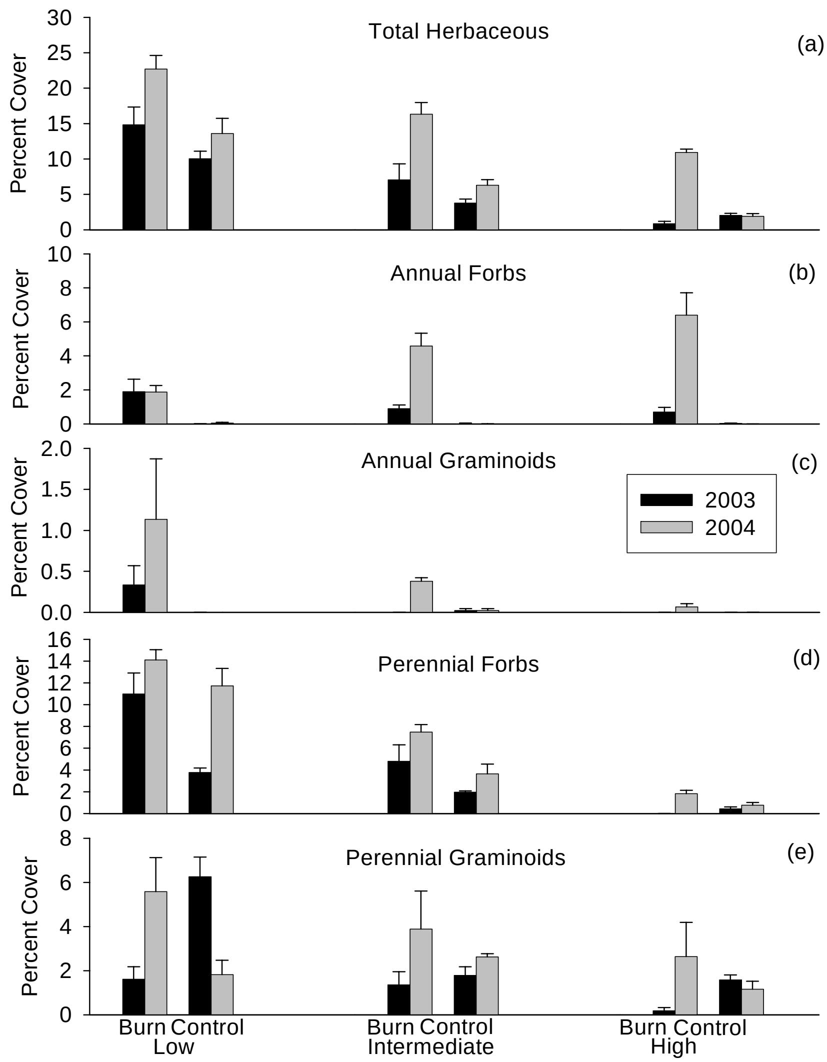


Figure 5. Aerial herbaceous cover for burn and control plots over tree cover gradient in 2003 and 2004. Values are means $\pm$ standard error.

The potential sage grouse diet on our sites was calculated as the sum of the cover values for the forbs that sage grouse utilize for their spring/ summer diet. These species include *Eriogonum* spp., *Astragalus* spp., *Crepis accuminata*, *Agoseris glauca*, *Collinsia parviflora*, *Phlox gracilis*, *Antennaria dimorpha*, *Antennaria rosea*, and *Phlox longifolia*. Elevation significantly affected the cover of these species (Figure 6). Aerial cover was highest at the intermediate elevation regardless of treatment. Burning had an overall effect with low and intermediate elevations showing greater cover of these important forbs at burn sites than their paired control sites. Tree cover had a significant effect on grouse food sources, with percent aerial cover decreasing as tree cover increased regardless of treatment. Cover for burn plots in 2004 exceeded that of their paired control plots at all tree cover class, suggesting a positive effect of burning on these sites.

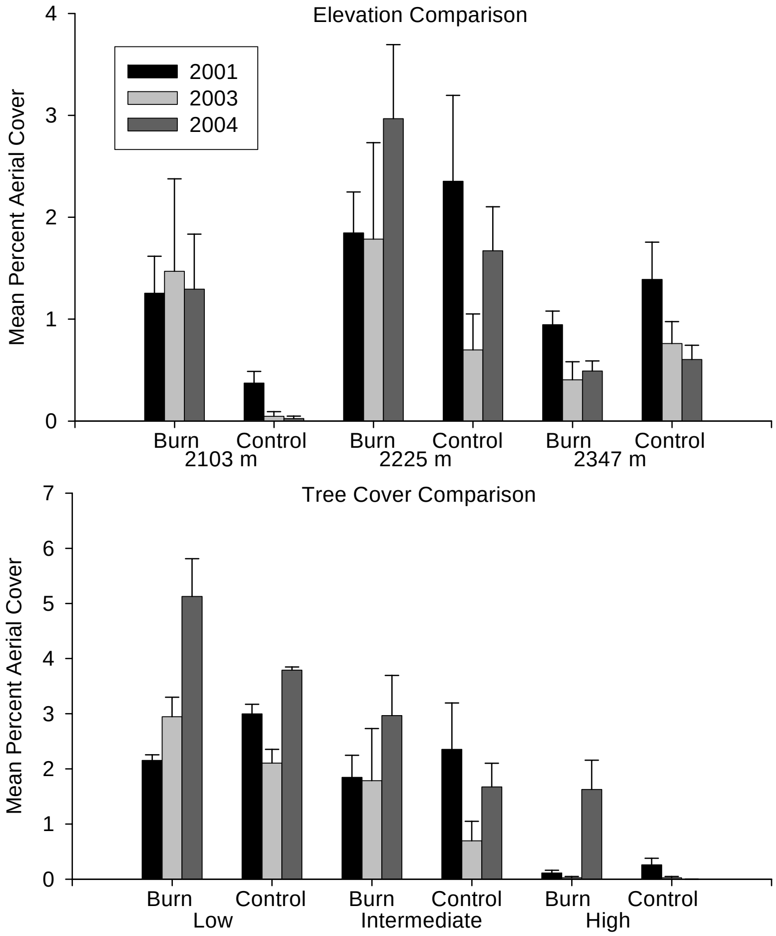


Figure 6. Aerial cover of forbs utilized by sage grouse as food. The top graph shows the elevation gradient analysis while the bottom graph shows the analysis for tree cover classes. Values are mean + standard error.

Results of this study have facilitated the development of a state-and-transition model that can be used for the management of fuels and fire in these ecosystems (Figure 7). Where tree overstory is at a relatively low to intermediate cover, natural or prescribed fire typically results in mortality of both the trees and non-root sprouting shrubs and creates suitable conditions for increases in understory herbaceous biomass. Areas with native herbaceous perennials in the understory usually return to native grass and forb communities. In the absence of fire, sagebrush increases over time, especially where overgrazing decreases competition from grasses and forbs. Repeated fire and proper grazing will maintain a successional mosaic dominated by varying proportions of shrubs and herbaceous species. Pinyon and juniper establishment is facilitated by shrubs, and given a tree seed source and the absence of fire the trees expand into shrub dominated communities. In the absence of fire, tree cover increases and there is a progressive depletion of understory shrubs and herbaceous species. If a biotic threshold has been crossed, fire can shift community dominance to native annual grasses and forbs, which may or may not recover to a sagebrush community depending on the presence of residual perennial natives and a seed source. The presence of invasive annual grasses can result in alternative vegetation communities, a grass-fire cycle, and progressive degradation of the site. More recently, exotic perennial forbs are invading these communities with unknown ecological consequences. Maintaining sustainable sagebrush ecosystems requires an understanding of community recovery potential at different stages of tree expansion.

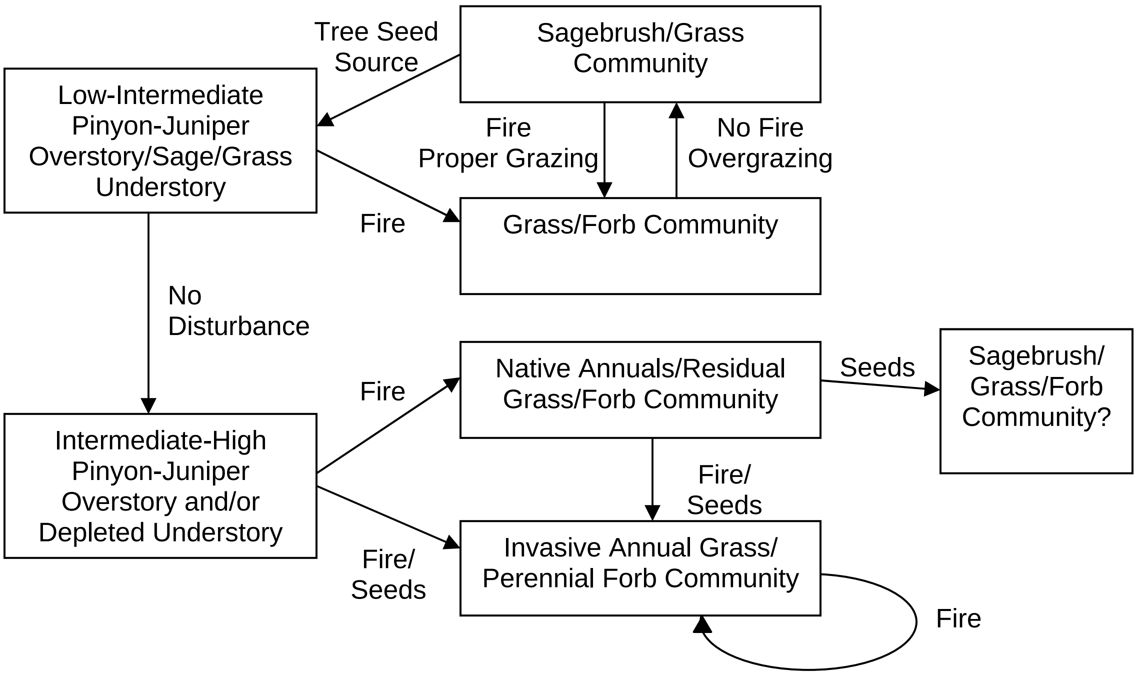


Figure 7. A state and transition diagram for pinyon and juniper ecosystems.

Fire Effects on Plant Nutritional Value

Pinyon and juniper expansion into sagebrush-grasslands has been shown to be detrimental to understory vegetation and sagebrush ecosystems. We examined the effects of spring prescribed fire on understory aboveground biomass and tissue nutrient concentrations of grass and forb species that occur in sagebrush ecosystems. This study was done in conjunction with the research on soil nutritional response to fire described above. The data are reported in a Master's thesis (Rau 2005) and a manuscript is in process (Rau et al. *submitted*). Six native understory plant species (*Crepis acuminata*, *Eriogonum umbellatum*, *Eriogonum elatum*, *Poa secunda secunda*, *Festuca idahoensis*, and *Lupinus argenteus*) important for native sagebrush obligate foragers were chosen to represent the understory plant community. *L. argenteus* is also important for system nutrient cycling and nitrogen fixation. Plants were collected from three microsites (under tree canopy, under shrub canopy, and interspace) common in transitional woodlands the summer before a spring prescribed burn and each of two summers following the burn. Soils were also collected from corresponding locations at two depths (0-8 and 0-52 cm) to determine burning x soil x plant x microsite interactions. Microsite had an impact on soil nutrients but was typically not reflected by plant tissue concentrations with the exception of *F. idahoensis.* Burning caused increases in soil surface and profile ortho-P and inorganic-N in both years following fire (Figure 8). All species studied had distinct nutritional characteristics and independent responses to burning. Burning did not affect aboveground plant biomass or nutrient concentrations in the first year with the exception of *F. idahoensis* which had increased tissue P. By the second year all species except *C. acuminata* had statistically significant responses to burning. The most common response was for increased aboveground plant weight and tissue N concentrations, e.g., the responses of *Eriogonum umbellatum* in Figure 9. Plant response to burning appeared to be best linked to the burn treatment and the soil variable profile ortho-P.

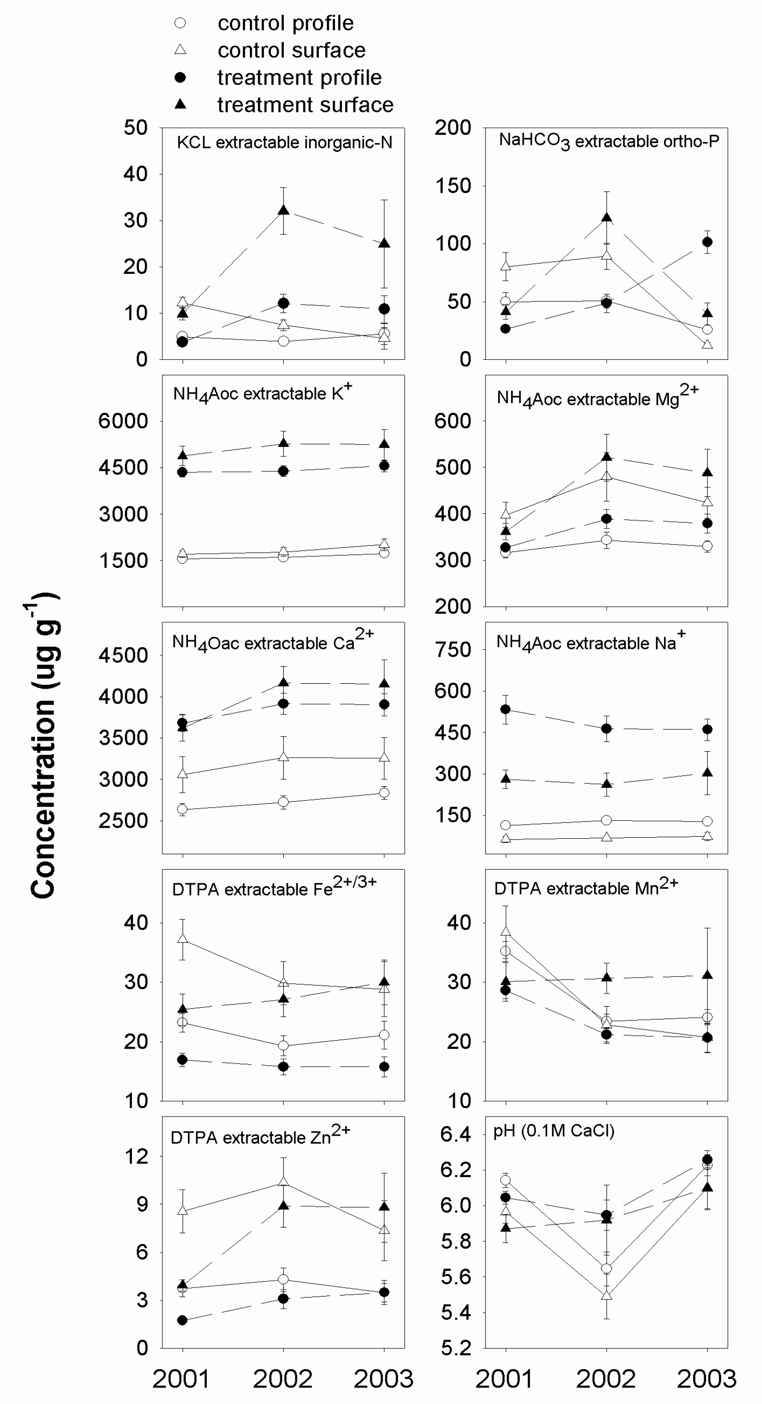


Figure 8. Mean extractable soil nutrient concentrations (ug g^{-1}) and standard errors in 2001, 2002, and 2003 for the soil surface (0-8cm) and soil profile (0-52cm) at the control (2195 m) and burned (2225 m) locations. P-values of means comparisons for control vs. burn sites in year 1 vs. 2, 1 vs. 3, and overall are indicated on each graph.

The percent cover of the species studied either was not affected or increased following fire. Increased cover coupled with increased understory plant biomass and tissue nutrient concentrations should increase above ground pools of mineral nutrients, and produce sites more favorable to native foragers including sage grouse. Fall burning in these woodlands may not have the same beneficial effects due to decreased fuel moisture and increased fire severity.

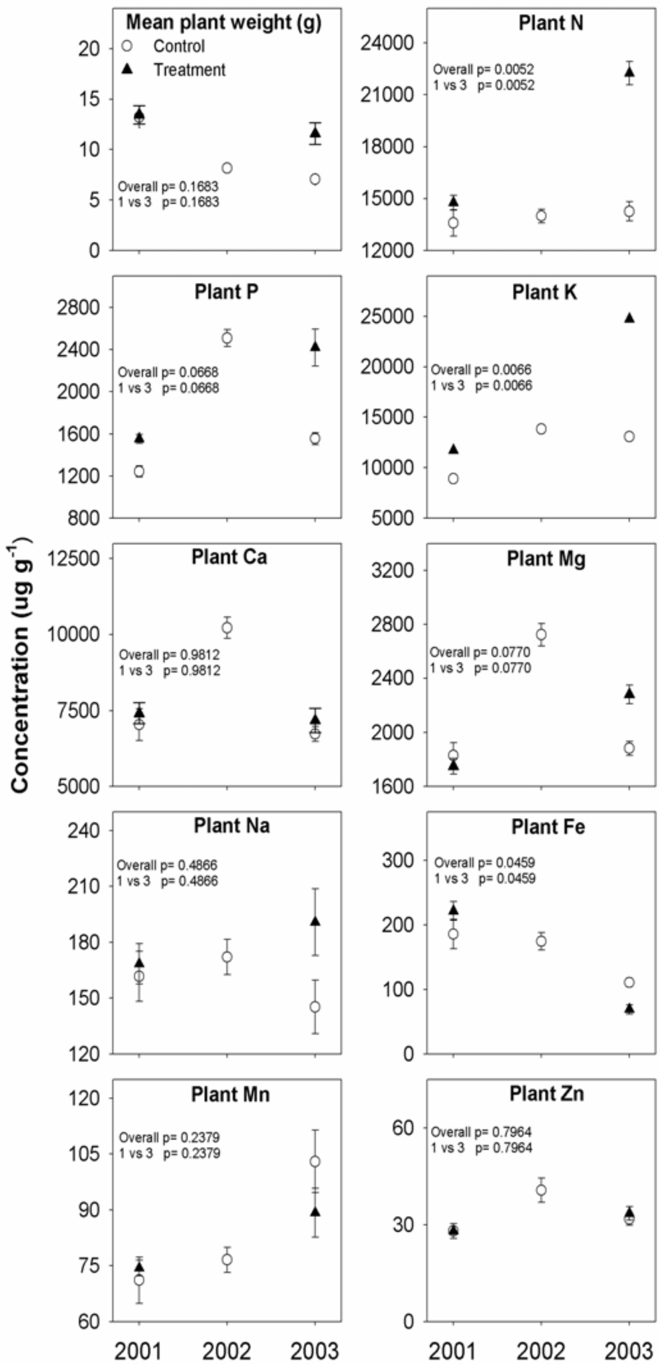


Figure 9. Mean above-ground plant weight (g), tissue nutrient concentrations (ug g^{-1}), and standard errors for *Eriogonum umbellatum* in 2001, 2002, and 2003 on the control (2195 m) and burned (2225 m) locations. P-values of means comparisons for control vs. burn sites in year 1 vs. 2, 1 vs. 3, and overall are indicated on each graph.

Fire Effects on Plant Establishment

We examined the effects of spring prescribed fire on seedling emergence and survival of native plant species that occur in sagebrush ecosystems and that are important for native sagebrush obligate foragers. This study was complimentary to the research described above on soil and plant nutrient relations following spring prescribed fire. A manuscript is in process (Board et al. *in preparation*). One shrub (*Artemisia tridentata vaseyana*), two forbs (*Eriogonum umbellatum* and *Lupinus argenteus*) and two grasses (*Poa secunda secunda*) and *Festuca idahoensis*) were selected from the understory plant community. Plants were seeded into three microsites (under tree canopy, under shrub canopy, and interspace) on the mid-elevation control and burn plots. Seeding was conducted on the control plot the fall before the spring prescribed burn (2001) and the fall after the burn (2002). Because of the delay in the small-scale burns, seeding was conducted on the burn plot only the fall after the burn (2002). Seedling emergence and survival was monitored on the control plot in summer (Figures 10 a & 10 b).

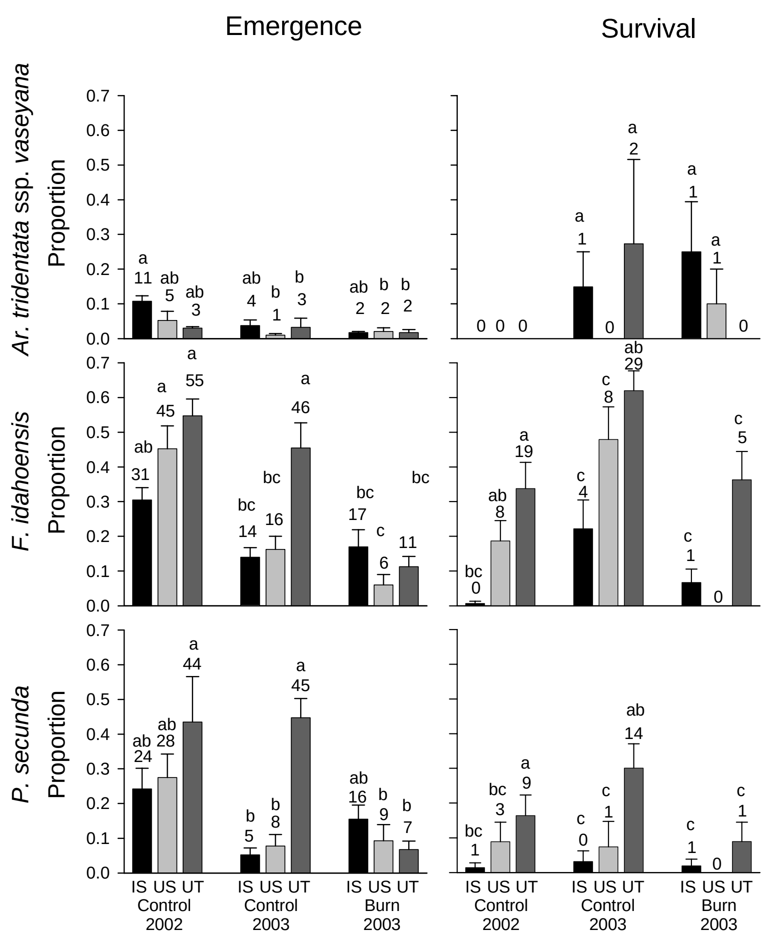


Figure 10 a. Proportional emergence and survival of *A. tridentata, F. idahoensis,* and *P. secunda* on control plots in 2002 and 2003 and burn plots in 2003 in interspace, undershrub and undertree microsites. The numbers of individuals that emerged and that were alive at the end of the study are indicated above the bars. Unlike letters indicate significant differences among years, treatments and microsites.

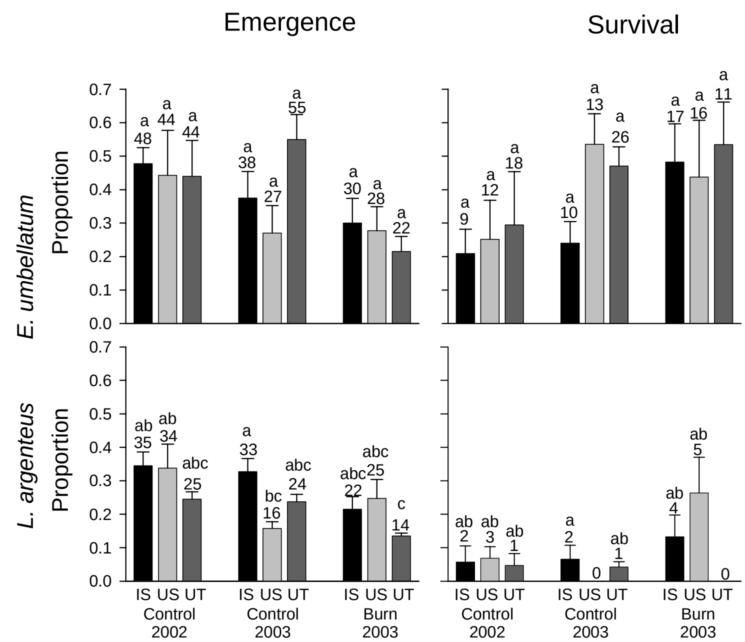


Figure 10 b. Proportional emergence and survival of *E. umbellatum* and *L. artgenteus* on control plots in 2002 and 2003 and burn plots in 2003 in interspace, undershrub and undertree microsites. The numbers of individuals that emerged and that were alive at the end of the study are indicated above the bars. Unlike letters indicate significant differences among years, treatments and microsites.

Emergence of the shrub, *A. tridentata vaseyana*, was generally low (Figure 10 a.). In 2002, none of the *Artemisia* seedlings that emerged survived. In 2003, *A. tridentata vaseyana* seedlings that emerged on the unburned sites under shrubs and on the burned site under trees did not survive. There were no other treatment differences in seedling survival. The two grasses had similar emergence and survival patterns (Figure 10 a.). In 2002 there were no differences in emergence among microsites. In 2003, a relatively dry year, overall emergence was lower and the under tree microsite had significantly higher seedling emergence than the other microsites. Both grass species had the highest survival under trees on the unburned site in both years. Survival was higher in 2003 than 2002 for both grasses. On the burned site, neither grass survived in undershrub locations and survival in under shrub locations was nil. The forbs exhibited different emergence and survival patterns than the grasses (Figure 10 b.). *Eriogonum umbellatum* had higher emergence than *L. argenteus*, but exhibited no difference in emergence among years, treatments or microsites. *Lupinus argenteus* had higher emergence in 2003 in interspaces on the unburned site, and interspaces had higher emergence than undertree areas on the burned site. *Eriogonum umbellatum* had higher survival than *L. argenteus*, but neither forb showed any differences among years, treatments or microsites. Seedling establishment in semi-arid ecosystems is typically low and varies among species.

Establishment of *Artemisia* species is episodic and, similar to other studies, was very low on the Demonstration area. Seedling establishment of the grass species was higher than that of *Artemisia*, but survival was still relatively low on the burn area. Overall emergence was high for both forb species and survival, especially of *E. umbellatum*, was relatively high on the burn plots. Forb species are an important component of the diets of sagebrush obligate species, and establishment of these species indicates that they could be seeded following prescribed fire to increase their composition on burned sites.

Fire Effects on Birds

From 2001 to 2005, data were collected on the distribution and abundance of breeding birds from a total of 298 points in the Shoshone, Toiyabe, and Toquima ranges (Humboldt–Toiyabe National Forest, Lander and Nye Counties, Nevada). At those points, we also collected data on vegetation structure, plant composition, and other attributes of bird habitat. Most of the points were located in pinyon-juniper or riparian woodland. Fourteen points were located in the Underdown Canyon Demonstration Watershed and ten were located in Riley Canyon, an adjacent control watershed. Eleven points (six “treated,” five control) were established in Wall Canyon (Toiyabe Range), in which a wildfire occurred in high-density pinyon-juniper woodland in 2000. We recorded a total of 88 species of birds from the project task area from 2001 to 2005. One species, Northern Goshawk, is identified as Sensitive by the U.S. Forest Service. An additional 23 species are priorities for Nevada Partners in Flight.

The total area treated with prescribed fire in the Underdown Canyon Demonstration Watershed prior to 2004 (~20 ha) was insufficient to assess reliably the response of birds and their habitats to watershed-scale burns. Multiple-year surveys in the Demonstration Watershed and beyond, however, afforded us a valuable opportunity to examine deterministic and stochastic influences on species richness and composition of birds. In addition, surveys provided insights to monitoring approaches likely to provide reliable information about biological responses to an array of environmental changes, including but not limited to fuels management. The following is a summary of some of the major inferences and conclusions based on this work.

Patterns and potential mechanisms of nestedness (Fleishman et al. 2002). Nestedness analyses test the degree to which species present in relatively species-poor locations are proper subsets of species present in relatively species-rich locations. One can predict the sequence in which species will be extirpated from or colonize a set of terrestrial or aquatic “islands” occupied by a nested assemblage; the accuracy of these predictions is positively correlated with the degree of nestedness, and does not depend on knowledge of underlying mechanisms. Assemblages can be nested by multiple phenomena, including but not limited to species-specific probabilities of extinction, species-specific probabilities of colonization, and nestedness of resources or habitat types. We used nested subsets analysis to examine distribution patterns of birds in 83 locations in the central Great Basin. Site area and topography did not appear to differ in their influence on nestedness of birds. In addition, riparian dependence had little discernible effect on nested distribution patterns of birds.

Elevational influences on species richness of birds (Fleishman and Dobkin in review). From 2001–2005, we conducted point counts in 218 locations in three mountain ranges. The mean elevation of riparian points (n = 103) versus non-riparian points (n = 115) was not significantly different across the three mountain ranges or within any mountain range. The proportion of riparian versus non-riparian points, however, differed considerably among the three mountain ranges. In the Toiyabe Range, 75% of points were riparian, as compared with 34% in the Shoshone Mountains and just 5% in the Toquima Range. The mean elevation of points dominated by different types of vegetation (aspen, mixed tree, pinyon-juniper, shrub, and willow) was not significantly different across the three mountain ranges or within any mountain range. The proportion of points dominated by trees versus shrubs differed somewhat among the three ranges (40% in the Shoshone Mountains, 69% in the Toquima Range, and 52% in the Toiyabe Range). When data for the three mountain ranges were pooled, several of the tested relationships between species richness and elevation were statistically significant, but only a small proportion of the variance in species richness was explained by elevation. All statistically significant correlations in the Shoshone Mountains, Toiyabe Range, and across the three mountain ranges were negative (species richness decreased unimodally as elevation increased), whereas all statistically significant correlations in the Toquima Range were positive (species richness increased unimodally as elevation increased). The response of species richness to elevation in the Toiyabe Range generally was not statistically significant. Dramatic differences among ranges in proportion of land-cover types and availability of surface water may drive the establishment of distinct avian assemblages with different numbers and proportions of riparian obligates and different distributional patterns.

Effects of spatial scale on species composition of birds (Mac Nally et al. 2004). We examined whether variation in species composition of breeding birds in the central Great Basin depended on sampling grain (the smallest resolvable unit of study) and on the relative proximity of sampling units across the landscape. Data were compiled at three sampling grains, sites (average 12 ha), canyons (average 74 ha), and mountain ranges. First, we investigated whether mean similarity of species composition among the three ranges differed as a function of the grain size at which data were compiled. Second, we explored whether mean similarity of species composition was greater for canyons within the same mountain range than for canyons within different mountain ranges. Third, we examined whether mean similarity of species composition at the site level was different for sites within the same canyon, sites within different canyons in the same mountain range, and sites within canyons in different mountain ranges. Mean similarity of species composition increased as the sampling grain increased. Mean similarity of species composition at the canyon level and site level was affected by relative proximity of sampling locations; turnover increased as the relative isolation of sampling locations increased. The sensitivity of turnover to sampling grain likely reflects the effect of local environmental heterogeneity: as sampling grain increases, biotic assemblages appear more homogeneous. The degree of variation in species composition suggested that spatially extensive sampling will be more effective for drawing inferences about regional patterns of species richness and composition than intensive sampling at relatively few, smaller sites.

Patterns of spatial autocorrelation of assemblages of birds, floristics, physiognomy, and primary productivity. We examined relationships between spatial patterns of species richness of birds and three attributes of birds' habitats, taxonomic composition of vegetation (floristics), physical structure of vegetation (physiognomy), and NDVI, a measure of photosynetically active radiation estimated from satellite images, at 279 locations in the central Great Basin (Mac Nally and Fleishman in review). We fitted spatial autocorrelation functions (semivariograms) to distance-based data for these four variables. The semivariogram for bird species richness was linear, whereas semivariograms for the three habitat variables were either spherical (vegetation composition) or power-law (vegetation structure, NDVI). The lack of relationships between spatial patterns of the three habitat variables and species richness suggests that species richness was not controlled by these variables. The spatial pattern for species composition of birds, in which the best-fit semivariogram was spherical with a 30-km range, was more concordant with spatial patterns of habitat variables such as vegetation composition (Fleishman and Mac Nally

2006). Resolving the disparity between patterns for species richness and assemblage composition of birds could provide valuable information, especially for conservation planning. Distinguishing between species on the basis of ecological specialization (i.e., functional groups or guilds) may be required to reveal relationships between spatial patterns of birds and their resources.

Remote sensing variables as predictors of species richness of birds (Seto et al. 2004). The ability to predict spatial patterns of species richness using a few easily measured environmental variables would facilitate timely evaluation of potential impacts of anthropogenic and natural disturbances on biological diversity and ecosystem function. Two common hypotheses maintain that faunal species richness can be explained in part by either local vegetation heterogeneity or primary productivity. We examined the potential of single-date Normalized Difference Vegetation Index (NDVI) data, which is associated with vegetation productivity and derived from Landsat Thematic Mapper (TM) images, to predict species richness of birds. Results indicated a positive correlation, but with no definitive functional form, between species richness and productivity. The strongest relationships between species richness of birds and NDVI were observed at larger sampling grains and extent, at which several measures of NDVI explained more than 50% of the variation in species richness.

Potential of bird conservation to protect co-occurring species (Betrus et al. 2005). Validation that conservation of certain species effectively protects a high proportion of co-occurring species is rare. Our previous work had suggested that an umbrella index based on geographic distribution and life history characteristics would maximize the proportion of conspecifics protected per unit area conserved. Using bird and butterfly data from three mountain ranges in the Great Basin, we examined whether umbrella species also would confer protection to species in different taxonomic groups. Further, we addressed the spatial transferability of umbrella species by considering whether species identified as umbrellas in one mountain range would be effective umbrellas in other mountain ranges. Overall, equal proportions of species would be protected using either cross-taxonomic umbrella species or same-taxon umbrella species. Our data suggested that in a given mountain range, umbrella species identified using data from the same mountain range versus a different mountain range would be equally effective. The ability of one set of umbrella species to confer protection to co-occurring species, however, may vary among taxonomic groups and geographic regions.

Potential of birds as indicators of species richness (Fleishman et al. 2005, Thomson et al. 2005). Indicator species models may be a cost-effective approach to estimating species richness across large areas. Obtaining reliable distributional data for indicator species (and therefore reliable estimates of species richness) often requires longitudinal data, that is, surveys for indicator species repeated for several years or time steps. Maximum information must be extracted from such data. We compared the influence of presence/absence data and reporting rate data (the proportion of survey years in which a species was present) on models of species richness based on indicator species. Using data on birds and butterflies, we evaluated models of species richness for one taxonomic group based on indicator species drawn from the same taxonomic group and from a different group. We also evaluated models of combined species richness of both taxonomic groups based on indicator species drawn from either group. We identified suites of species whose occurrence patterns explained as much as 70% of deviance in species richness of a different taxonomic group. Validation tests revealed strong correlations between observed and predicted species richness, with 83–100% of the observed values falling within the 95% credible intervals of the predictions. Whether reporting rate data improved the explanatory and predictive ability of cross-taxonomic models depended on the taxonomic group of the indicator species. The discrepancy in predictive ability was smaller for same-taxon models. Our methods provide a manager with the means to maximize the information obtained from longitudinal survey data.

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